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# Potential of Oil Palm Empty Fruit Bunch (EFB) Biochar from Gasification Process

[1]Muhammad Afif Ariffin, [1]Wan Mohd Faizal Wan Mahmood, [2]Mohd Tusirin Mohd Nor and [3]Ramizi Mohamed

[1]*Universiti Kebangsaan Malaysia, Department of Mechanical & Material Engineering, Faculty of Engineering & Built Environment, 43600 UKM Bangi, Selangor, Malaysia*
[2]*UKM-YSD Sustainable Development Chair: Zero Waste Technology,*
[3]*Universiti Kebangsaan Malaysia , Department of Electrical, Electronic & Systems Engineering, Faculty of Engineering & Built Environment, 43600 UKM Bangi, Selangor, Malaysia*

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**ABSTRACT**

**Background:** This paper focuses on the potential of empty fruit bunch (EFB) biochar which based on its physicochemical properties. EFB biochar was prepared by the EFB gasification process using medium scale downdraft gasification with 500kg of a feedstock capacity. **Objective:** The process was performed at reactor temperature 850 ºC with gasification cold gas efficiency (CGE %) of 80%. The characteristic of EFB biochar in terms of physicochemical properties such as calorific value, elemental content, surface area and adsorption capacity were investigated using bomb calorimeter, CHNS-O analyzer and Brunauer–Emmett–Teller (BET) method. **Results:** The EFB biochar has shown a favorable characteristic in application of further energy conversion and soil amendment due to the high calorific value (26.6 MJ/kg), high carbon content (75%), moderate surface area (95.83$m^2$/g) and moderate adsorption capacity (35$cm^3$/g). **Conclusion:** The EFB biochar in soil applications has potential as a carbon sequestration due to the capability storing carbon for long period, hence, preventing it from being released to the atmosphere and mitigating greenhouse gases .



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## INTRODUCTION

Biochar is a promising by-product from gasification process to be used as a carbon sequestration or further combustion for energy. Basically, the gasification process will produce three main products namely syngas, tar and biochar, each of which has potential economic value. In fact, biochar is categorized as a by-product from the process. It commonly is produced via thermochemical process under low oxygen at temperatures between 300 to 1000°C (Jeffery, S., 2011). The utilizations of biochar to soils is currently a global interest due to its potential as a carbon sequestration, improve soil fertility, improve soil nutrient retention capacity, water holding capacity and also to sustainable store carbon, thereby reducing greenhouse gas (GHG) emissions (Song, Y., 2012; Yao, Y., 2011). Other than that, the biochar itself can be applied for further energy conversion, for soil amendment and other uses. However, the applications and functions of those biochar are highly dependent on their physicochemical properties such as elemental composition and surface area (Yao, Y., 2011). Thus, it is very important to investigate the characteristic of biochar and identify its potential.

There are biomasses that have the potential to be used as a feedstock for biochar production like agricultural crop residues, forestry residues, wood waste and the organic portion of municipal solid waste (MSW). Oil palm waste is one of the biomass that has a big potential as a feedstock in biochar production processes. Among the oil palm wastes, empty fruit bunch (EFB) has the big potentials for feedstock in biochar production due to the abundance of supply and readily available source. According to Malaysia Palm Oil Board (MPOB), 21.45 megatons of empty fruit bunch were produced in 2011 and its usage is still underutilized (Malaysia Palm Oil Board (MPOB), 2011). Hence, a study should be performed to explore its potential. Currently, many studies have been done for energy conversion of EFB via thermochemical processes especially using gasification process. The studies mostly focused on the syngas production and process efficiency but not for its by-product like EFB biochar. Thus, this paper will focus on the potential of EFB biochar based on its characteristic in terms of its physicochemical properties.

**Corresponding Author:** Muhammad Afif Ariffin, Wan Mohd Faizal Wan Mahmood,Universiti Kebangsaan Malaysia, Department of Mechanical & Material Engineering, Faculty of Engineering & Built Environment, 43600 UKM Bangi, Selangor, Malaysia
Tel: 60013-3179887; E-mail: afif@siswa.ukm.edu.my

***Experimental Procedure:***

Empty fruit bunches (EFB) were taken from the palm oil mills in areas of Selangor, Malaysia. The EFB was chipped and dried to the 15% of moisture content. The readily EFB chips were briquetted using the briquetting machine into cubic forms (3x3x5 cm). The feedstock was gasified by using medium scale downdraft gasification with 500kg of feedstock capacity. The gasification process run at feeding rate 126 kg/hour and syngas flow rate 362m$^3$/hour. The gasification process used a closed loop system which tar recycling system. Hence only two products were yielded, namely syngas and biochar. The biochar yield was collected to determine its characteristic.

The calorific value of the EFB biochar was determined by using a bomb calorimeter brand IKA-WERKE, model of C 5003/C 5001. Meanwhile, the elemental contents in the EFB biochar such as carbon, hydrogen, nitrogen, sulphur and oxygen were determined using CHNS-O analyzer brand Fison, model EA 1108. In this experiment, the surface area and adsorption capacity of the sample were determined using the Brunauer–Emmett–Teller (BET) method with $N_2$ adsorption at -196 ºC.

## RESULT AND DISCUSSION

Figure 1 (a) shows oil palm empty fruit bunches (EFB) biochar production during the EFB gasification. About 6% of EFB biochar was produced during the gasification process at gasification cold gas efficiency (CGE %) of 80%. Due to the high gasification (CGE %), most of the product is syngas with 93% of the share. If necessary, the EFB biochar can be increased by reducing the gasification CGE. Basically the gasification CGE is dependent of the syngas calorific value, syngas flow rate and reactor temperature. During the process, these parameters were controlled by a blower system, where a higher blower speed will increase these parameter values. Thus, higher EFB biochar production can be obtained at slower blower speed operation. Besides that, the biochar production can also be increased by reducing the residence time of the process. The reason for this is when minimum residence time was applied to the process, less biochar will be involved in the boudouard and water gas reactions to produce more syngas yield. Therefore, more biochar yielded when the residence time was minimized.

In figure 1 (b), the EFB feedstock and biochar calorific value are shown. The biochar calorific value (26.6 MJ/kg) is higher compared to its feedstock (16.4 MJ/kg). It indicates that much more energy was stored in the biochar during the EFB gasification. In fact, the biochar calorific value is almost similar with coal calorific value. This happened due to vaporization of low calorific value elements such as oxygen, hydrogen and nitrogen and left high calorific value element namely carbon as residue. The process is commonly known as carbonization process. Based on the EFB biochar calorific value, it is ideal to be used for further gasification and recycling the biochar in the EFB gasification process is an option to be applied.

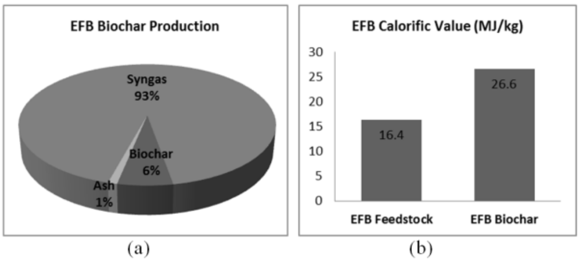


**Fig. 1:** (a) EFB Gasification products and (b) Calorific Value of EFB Biochar

Figure 2 shows a comparison of elemental content in the EFB feedstock and biochar. Both samples show that carbon content is the highest element share of them, followed by oxygen, nitrogen and hydrogen content. It can also justify the carbonization process by referring to the carbon content of both samples. EFB biochar shows very high carbon content (75%) compared to EFB feedstock (47%). It indicates that only a small portion of carbon content that participated in the vaporization compared to others. The drastic reduction of oxygen share also indicates that more oxygen content was contributed during the thermochemical process (gasification). Based on the carbon content in the EFB biochar, the biochar is ideal to be used as a soil application for carbon sequestration strategy. It can store the carbon from being released to the atmosphere for a long time thereby mitigating the greenhouse gases. Other than that, nitrogen content in the EFB biochar is also good for nutrient supply in the agricultural application and can reduce the fertilizer usage. Thus, based on the elemental content in the EFB biochar, it is ideal to be used as a soil application hence acts as carbon sequestration.

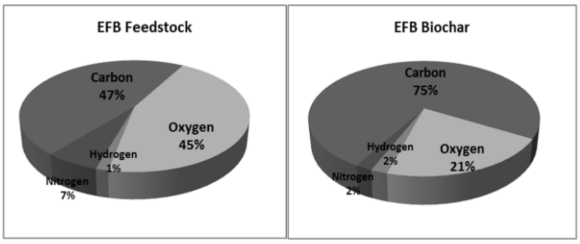


**Fig. 2:** (a) and (b) Elemental content of EFB feedstock.

The surface area was determined by measuring meter square per gram ($m^2$/g) of the sample according to the standard by using Brunauer–Emmett–Teller (BET) method. The surface area is very important to know the potential of using the EFB biochar. High surface area is important for effective and versatile adsorbent of biochar because the surface area is directly proportional to the adsorption capacity. The BET surface area of EFB biochar is moderately high with 95.83$m^2$/g. Figure 3 shows the adsorption of biochar at a certain pressure. The adsorption capacity of EFB biochar is slightly moderate with 35$cm^3$/g at standard atmosphere pressure ($p/p_o$). It is good for organic storage and water retention for the plant as well as providing good ventilation for the plant root. Therefore, this justifies that the EFB has a big potential to be used in soil application due to the ideal adsorption capacity for agricultural application.

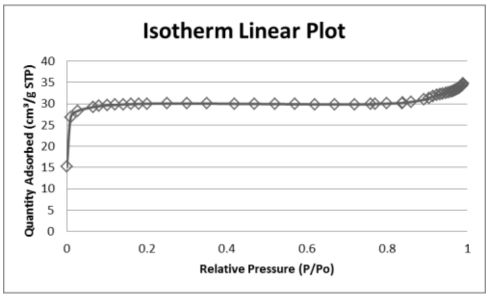


**Fig. 3:** Adsorption Capacity of EFB Biochar.

***Conclusion:***

The empty fruit bunch is a promising by-product of the gasification process for some applications. It can be used in soil application and also for further energy conversion. Based on this physicochemical study, it can be shown that it has high calorific value (26.6 MJ/kg) which is ideal for further energy conversion. Other than that, it also has high carbon content (75%), moderate high surface area (95.83$m^2$/g) and adsorption capacity (35$cm^3$/g), which is ideal in soil application, hence acts as a carbon sequestration due to the long time carbon storing. Therefore, the EFB biochar from gasification process has a big potential in other applications such as for further energy conversion and soil applications. Its usage not only gives benefits in terms of economic potential, but also can mitigate greenhouse gases.

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